

Trends, Power and Sample Design: Lessons Learned During 7 Years of Coral Reef Monitoring

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Study Sites

Lines show boundary of study site established using SONAR mapping system. Transect start points randomly placed within boundary.

Newfound Reef
Outside Virgin Islands NP
Sampled: 1999-2005
Area= 13,768 m²



Yawzi Reef
Virgin Islands NP
Sampled: 1999-2005
Area= 7,125 m²



Haulover Reef
Virgin Islands NP
Sampled: 2003-2005
Area= 13,568 m²



Mennebeck Reef
Virgin Islands NP
Sampled: 2000-2005
Area= 12,495 m²



Western Spur and Groove
Reef, Buck Island Reef NM
Sampled: 2000-2005
Area= 26,365 m²



South Fore Reef
Buck Island Reef NM
Sampled: 2002-2005
Area= 40,752 m²



Bird Key Reef
Dry Tortugas NP
Sampled: 2004-2005
Area= 19,765 m²



Ball Buoy Reef
Biscayne NP
Sampled: 2004-2005
Area= 14,136 m²



Amanda's Reef
Biscayne NP
Sampled: 2004-2005
Area= 20,240 m²



Coral Cover

Values of % cover by live coral at 9 study sites. Significant trends identified by trend-line and p- value. 20 transects represented by symbols.

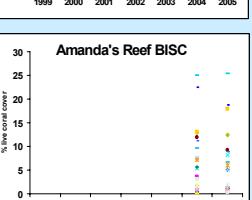
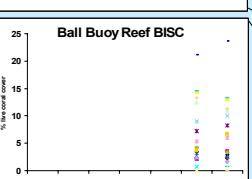
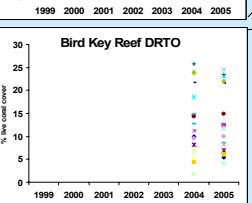
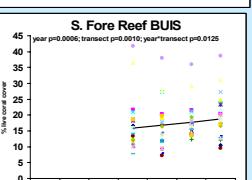
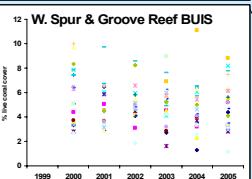
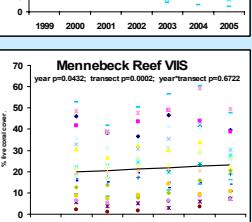
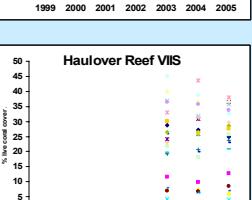
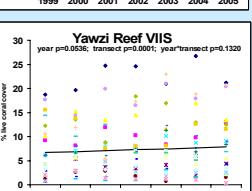
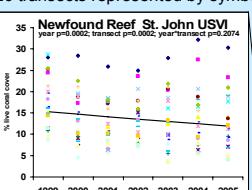
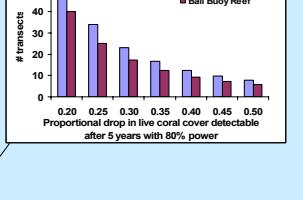
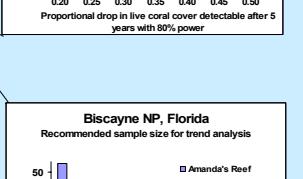
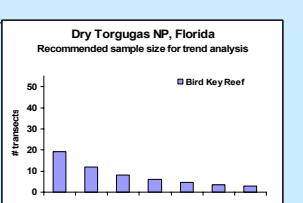
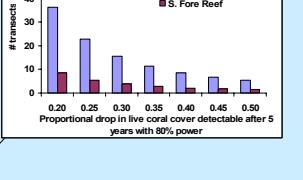
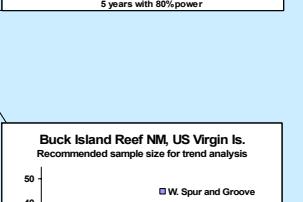
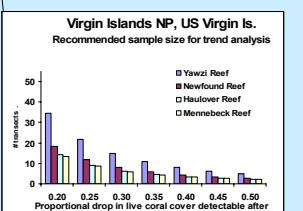


Table 1. Site averages, coefficients of variation (s / \bar{x}), and power of current design to detect a proportional change in mean coral cover of 0.25 over 5 years (0.05 trend per year; $\alpha = 0.05$)

Permanent transects			
Site	Avg.	CV	Power
Newfound Reef	13.6	9.6%	92%
Yawzi Reef	7.3	12.4%	74%
Haulover Reef	20.7	8.6%	96%
Mennebeck Reef	21.5	8.4%	97%
W. Spur & Groove	5.0	12.0%	76%
S. Fore Reef	17.3	6.5%	100%
Bird Key Reef	12.2	9.7%	91%
Ball Buoy Reef	5.7	12.9%	70%
Amanda's Reef	5.7	15.0%	57%

Non-permanent, Annually, re-randomized transects			
Site	Avg.	CV	Power
Newfound Reef	13.8	27.3%	21%
Yawzi Reef	6.9	35.8%	14%

Sample Size Calculations by NPS park unit ($\alpha=0.05$, power=80%)



Introduction: As part of the National Park Service South Florida / Caribbean Prototype monitoring program, the US Geological Survey and National Park Service developed a protocol for monitoring selected coral reef communities. Implemented in 1999 at Virgin Islands NP, this protocol is now being implemented as a pilot project at nine sites in four National Parks within the South Florida / Caribbean Network Inventory and Monitoring Program.

Field methods: Pilot study sites were chosen based on historical work, areas of particular concern, and/or interest to managers. Once selected, each site is mapped using a SONAR mapping system which allows rapid delineation of the study area. Within the study area, 20 sample points are randomly selected (see maps far left) and permanent ten meter transects originate from each sample point. Transects are filmed annually with a digital video camera in underwater housing. Videotapes are played through a PC to capture adjacent non-overlapping still images. Ten random points are superimposed upon each image and the benthic component under each point is identified (25-30 images per transect x 10 points per image results in 250-300 points per transect). Percent live stony coral cover as well as cover of other major benthic functional groups are calculated by transect.

Trend analysis and results: Percent live coral cover for each transect was transformed for analyses using a $\sqrt{x+1}$ transformation. Sites were analyzed separately for trends using a repeated measures analysis of covariance design with year as the repeated measure nested within transects using SAS 9.1.3. A first-order autoregressive covariance structure was used. A year*transect interaction was added for sites with more than 2 years of data.

Three reefs showed small but statistically significant trends: Mennebeck ($\uparrow 3.9\%$, $p=0.0432$), Newfound ($\downarrow 3.3\%$, $p=0.0002$), S. Fore Reef ($\uparrow 5.4\%$, $p=0.0006$; year*transect, $p=0.0125$). Yawzi Reef was also nearly significant ($\uparrow 1.2\%$, $p=0.0536$)

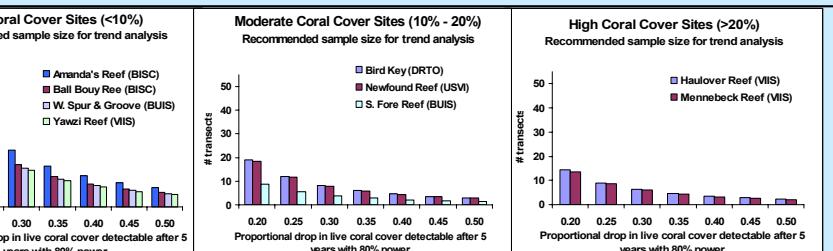
Power of current design (see Table 1): The following equation was used to calculate the power ($1-\beta$) of 20 transects to detect a proportional change in mean coral cover of 0.25 over 5 years (i.e. +/- .05 proportional change (trend) per year):

$$n = 12 * \frac{(s / \bar{x})^2 * (t_{\alpha/2, df} + t_{\beta, df})^2}{r^2 * y^3} \quad \text{where } n = \# \text{ transects; } r = \text{change/year; } y = \# \text{ sampling events} = \# \text{ years; } \bar{x} = \text{avg. coral cover; } s^2 = \text{mean square error from analysis of covariance above, } df = (y-2)*n$$

(adapted from Gerrodette as reported in Thompson, W. L., G. C. White, C. Gowan, 1998, *Monitoring Vertebrate Populations*, Academic Press, San Diego, CA, p. 181)

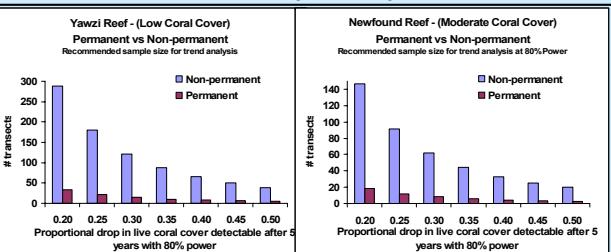
Sample size calculations: The equation above was used to calculate the number of transects needed to detect proportional changes of the mean of 0.20-0.50 after 5 years (i.e. 0.04-0.10 trend per year) at 80% power (1- β).

Results are graphed to the left. Sites were also grouped into low, medium, and high coral cover sites and graphed below. Calculated sample sizes for high cover sites ranged from 9-10 transects to detect a proportional drop of the mean of 0.25 with 80% power. Moderate cover sites ranged from 6-12 transects. Low cover sites ranged from 22-34 transects to detect a proportional drop of 0.25, but could detect a drop of 0.35 with 11-17 transects.



Sample size for permanent vs. non-permanent transects: For 2 years at Yawzi Reef and 3 years at Newfound Reef an additional 20, non-permanent, annually re-randomized transects were monitored. These sites were analyzed using a Analysis of Covariance without repeated measures.

The sample sizes calculated necessary to detect trends are presented below. The non-permanent transects required over 7 times as many transects as the permanent transects to detect trends with equivalent power.



CONCLUSIONS:

Trends: Some short-term trends are occurring in 4 sites, all but one of which were positive trends.

Power of current design: The current sampling design at moderate to high coral cover sites has a power of over 90% to detect trends of at least 0.25 proportional change in the mean over 5 years (0.05 change per year). At low cover sites (< 10% coral cover) the current design ranged from 57-76% power to detect the same change.

Sample size calculations: Based upon the sample size calculations, the number of transects can be reduced to 12 per site for medium and high cover sites to allow detection of a 0.25 proportional change in mean coral cover over 5 years with 80% power. Low cover sites need up to 17 transects to detect only a 0.35 proportional change in mean cover over 5 years.

Permanent vs. non-permanent transects: Non-permanent transects require over 7 times the sample size of permanent transects to detect trends with equivalent power. The power of the current design (20 transects) to detect a 0.25 proportional change in mean coral cover over 5 years was only 14-21%. To increase the power to 80% would require 92 transects for Newfound Reef and 181 transects for Yawzi Reef.